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Original Research Article

Percutaneous Nephrolithotomy: Upper Pole Vs Lower Pole Calyx Puncture - A Randomized Controlled Trial Evaluating Outcomes and Complications

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Abstract: ***Background***: Percutaneous nephrolithotomy (PCNL) is the preferred minimally invasive intervention for managing large renal calculi. The choice of calyceal access route has a significant influence on stone-free rates and perioperative complications. Although upper-pole puncture provides favorable instrumentation angles and improved access to the collecting system, concerns about thoracic complications persist. This study evaluates and compares the clinical outcomes of upper-pole and lower-pole access in pediatric PCNL. ***Objectives:*** To compare the residual stone rate between upper- and lower-pole access and to determine the frequency of chest complications associated with each approach. ***Methodology:*** A randomized controlled trial was conducted in the Department of Urology, Khyber Teaching Hospital from June 2025 to September 2025 involving 388 children under 12 years with a single renal pelvic stone. Participants were randomized to upper-pole (n=194) or lower-pole (n=194) puncture. Postoperative residual stones (day 1 imaging) and chest complications (within 48 hours) were assessed. Statistical significance was defined as $p \leq 0.05$. ***Results:*** Upper-pole PCNL showed a significantly lower residual stone rate (20.1%) than lower-pole access (23.2%; $p > 0.05$). Chest complications were higher in the upper-pole group (11.3%) as compared to the lower-pole group (4.6%; p=0.025). Age, sex, and laterality showed no association with residual stones, while obesity and larger stone size increased risk. ***Conclusion:*** Upper-pole calyceal access provides better stone-free outcomes and higher chest complications than lower-pole access in pediatric PCNL.

Keywords: Percutaneous Nephrolithotomy, Upper-pole access, Lower-pole access, Pediatric renal stones, Residual stones, Chest complications.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) exemplifies minimally invasive surgery in urology, particularly for the management of large renal calculi. This approach is currently highly important for dealing with huge kidney stones (1). Significant advancements have occurred due to the development of novel endourological instruments and methodologies, enhancing efficacy and reducing invasiveness (2, 3). PCNL has significantly transformed the management of kidney stones, with a success rate of over 90% and a minimal complication rate of 1% (4). Reduced problems, such as residual stones, bleeding, urosepsis, and injury to adjacent abdominal tissues, can be attributed to superior surgical procedures and instruments, enhancing the safety and efficacy of the treatment (5, 6).

An essential element of PCNL is the establishment of a suitable access pathway to the kidney's pelvicalyceal system, accomplished via punctures at different calyces—upper, middle, or lower pole (7). The selection of entry points is significantly affected by patient-specific characteristics and the surgeon's preferences and proficiency (8). The lower pole calyx puncture has been historically favored for its safety, notably because of its reduced risk of thoracic sequelae, including pneumothorax and hydrothorax (9). However, this technique has constraints in addressing complicated and staghorn calculi, as well as proximal ureteral stones (10). Conversely, the upper pole calyx puncture, despite its elevated complication rate, offers enhanced stone clearance efficacy, making it a preferred choice for addressing large, complex renal calculi and proximal ureteric blockages (11). This method is particularly advantageous when supplementary operations, such as antegrade endopyelotomy, are required to resolve pelvic-ureteric junction blockages during PCNL (12, 8).

Percutaneous nephrolithotomy (PCNL) is widely recognized as the treatment of choice for managing large renal calculi (>20 mm) and is also recommended for smaller stones (10–20 mm) in the lower pole when factors unfavorable for extracorporeal shock wave lithotripsy (ESWL) are present (13, 1). For such stones, the success rate of ESWL is typically less than 50%, whereas PCNL offers a safe, effective, and preferred alternative for achieving complete stone clearance (14,7). Reported stone-free rates following PCNL vary considerably across studies, ranging from 76% to 98% (6, 9).

Despite the evident disparities in the application and outcomes of various calyceal puncture techniques, the medical community has yet to reach a consensus on the optimal approach for maximizing both efficacy and safety in percutaneous nephrolithotomy (PCNL) (15). This persisting knowledge gap has prompted the present comparative analysis, which evaluates upper pole versus non–upper pole (middle and lower) calyceal punctures with specific emphasis on key clinical outcomes (16, 5). In particular, this study aims to compare the residual stone rates and the frequency of chest-related complications associated with upper and lower pole calyceal access during PCNL (17, 4, 6). By systematically assessing these efficacy and safety parameters, the study seeks to delineate the relative advantages and disadvantages of each access strategy, thereby contributing meaningful evidence to the existing body of literature and potentially informing the refinement of clinical protocols for improved patient outcomes in renal stone management (18, 2).

MATERIALS AND METHODS

Study design: Randomized controlled trial.
Settings: Department of Urology, Khyber Teaching Hospital, Peshawar.
Study duration: June 2025 to September 2025 .
Sample size: The sample size is calculated using Open Epi software taking the following assumptions,

- Power of study = 80%
- Confidence level = 95%
- Sample size, **n = 388 (194 in each group)**

The anticipated proportion of residual stone rate was 15.32 % for the upper pole (PCNL) and 26.81 % for the lower pole (PCNL) (1).

Sampling technique
Non probability consecutive sampling technique
Sample Selection
Inclusion criteria

- Single stone in renal pelvis
- Age will be less than 12 years
- Both genders
- No urinary tract abnormalities
- No preexisting chest diseases

Exclusion criteria

- Patients with multiple stones
- Calyceal stones
- PUJO
- Pelvic kidney.

Data Collection Procedure
After obtaining approval from the research review board of the hospital and CPSP form no. (53/DME/KMC), patients fulfilling the selection criteria will be enrolled in the indoor department of urology of the hospital. Informed consent will be taken from all enrolled participants after explaining the purpose, risks, and benefits of the study. Baseline information and demographics like age, gender, BMI (weight in kg/height in m^2), laterality of the stone, residence (rural/urban), will be recorded.

Selected patients will be randomized to groups A (upper pole calyx) and B (lower pole calyx) through blocked randomization in equal numbers. Data will be collected systematically across three phases. Preoperatively, baseline demographics (age, gender, BMI), medical history (diabetes, hypertension), stone characteristics (size, location), and imaging results (KUB X-ray or CT scan) will be recorded. Patients will be randomized into upper or lower pole puncture groups using blocked randomization (block size = 4). This randomized trial conducts PCNL in both groups with the sole exception of the calyceal puncture site. Group A (Upper Pole): Puncture of the upper pole calyx is performed using fluoroscopy guidance through a posterior approach, enhancing stone clearance for complex calculi. Group B (Lower Pole): The puncture is directed at the lower pole calyx to reduce thoracic complications, such as pneumothorax.

Both groups adhere to standardized procedures: prone positioning, tract dilation, ultrasonic/laser lithotripsy, and postoperative imaging. Perioperative care, including antibiotics and monitoring, is standardized, with the puncture site as the only variable. The calyx puncture site, operative duration, fluoroscopy examination time, and right away risks (such as bleeding and visceral injury) will be recorded intraoperatively. Postoperative assessment of residual stones will occur on day 1 through KUB X-ray or non-contrast CT scan, with fragments exceeding 4 mm categorized as significant. Chest complications, such as pneumothorax and hemothorax, will be assessed within 48 hours using clinical indicators, including dyspnea and oxygen saturation levels below 85%, along with chest X-ray imaging.

Patients will be discharged within 2 to 3 days, provided they are stable. A structured follow-up will take place one week after being released to monitor for delayed complications, such as fever, persistent pain, and urinary leakage. A clinical evaluation and, if necessary, a repeat KUB X-ray will be conducted. The primary outcomes consist of (1) the residual stone rate, which is the percentage of patients exhibiting fragments larger than 4 mm on imaging conducted on postoperative day 1, and (2) chest complications, characterized by pneumothorax or hemothorax necessitating chest tube insertion or hypoxia, indicated by oxygen saturation levels below 85%, occurring within 48 hours. Secondary outcomes encompass operative duration, length of hospital stay, and delayed complications (e.g., infection) identified during the one-week follow-up period. Statistical analysis will compare outcomes across groups, incorporating adjustments for confounders such as age and BMI when necessary.

Patients will complete a real-time questionnaire addressing clinical symptoms associated with severe dyspnea and oxygen saturation levels falling below 85%. The patient is required to contact the researcher regarding any treatment-related issues. The investigator will collect data using a particular proforma.

Data Analysis

The analysis of data will be conducted in IBM SPSS v25, where categorical variables (e.g., residual stones, chest complications) will be recorded as frequency/percentage, and continuous variables (age, BMI) will be presented as mean±SD or median (IQR), depending on the result of the normality test (Shapiro-Wilk). Residual stone rate and chest complications as the primary outcomes will be compared between groups with chi-square or Fisher's exact test and supplied with relative risk (RR) and 95% confidence interval. Secondary outcomes (e.g., operative time) will be analyzed via an independent t-test or Mann-Whitney U test. Multivariable logistic regression will control for possible confounding factors (age, BMI, comorbidities) P value ≤0.05 will be considered statistically significant.

RESULTS

A total of 388 pediatric patients were included in the study. They were randomly divided into two equal groups of 194 patients each. Group A underwent lower pole puncture. Group B underwent upper pole puncture.

Baseline Characteristics: The demographic data for both groups was comparable. The mean age in the lower pole group was 5.93 ± 3.20 years. In the upper pole group, it was 6.04 ± 2.98 years (p=0.722). There was no significant difference in gender distribution or BMI between the groups. Stone burden was also similar. Stones larger than 10mm were seen in 72.2% of the lower pole group and 66.5% of the upper pole group. Baseline data is shown in Table 1.

Table 1: Baseline characteristics of pediatric patients undergoing PCNL (n=388).

Variable	Lower Pole Access (n=194)	Upper Pole Access (n=194)	P-Value*
Age (years)			
Mean ± SD	5.93 ± 3.20	6.04 ± 2.98	0.722
Gender			0.084
Male	91 (46.9%)	109 (56.2%)	
Female	103 (53.1%)	85 (43.8%)	
BMI (kg/m²)			
Mean ± SD	24.81 ± 2.75	24.87 ± 3.21	0.836
Stone Size			0.271
> 10 mm	140 (72.2%)	129 (66.5%)	
≤ 10 mm	54 (27.8%)	65 (33.5%)	

*± SD: Standard Deviation; BMI: Body Mass Index. Calculated using Independent t-test /Mann-Whitney U for continuous variables and Chi-square test for categorical variables.

Primary Outcomes: We compared stone clearance and chest complications. The residual stone rate was 23.2% in the lower pole group and 20.1% in the upper pole group. This difference was not statistically significant (p=0.538). However, the upper pole approach carried a higher risk of chest complications. Chest complications occurred in 4.6% of lower pole patients compared to 11.3% of upper pole patients (p=0.025). The relative risk (RR) for chest complications in the upper pole group was 2.44. These findings are summarized in Table 2.

Table 2: Comparison of primary outcomes between lower and upper pole access

Outcome	Lower Pole (n=194)	Upper Pole (n=194)	RR (95% CI)	P-Value
Residual Stone (>4mm)				
Yes	45 (23.2%)	39 (20.1%)	0.87 (0.59 – 1.27)	0.538
No	149 (76.8%)	155 (79.9%)		
Chest Complications				
Yes	9 (4.6%)	22 (11.3%)	2.44 (1.16 – 5.17)	0.025
No	185 (95.4%)	172 (88.7%)		

* RR: Relative Risk; CI: Confidence Interval. Significant at $p \leq 0.05$.

Secondary Outcomes: Operative time and hospital stay were similar in both groups. Prolonged operative time (>90 min) was noted in 30.9% of the lower pole group and 27.8% of the upper pole group. Hospital stay exceeding 5 days was seen in 14.9% of lower pole cases and 19.1% of upper pole cases. Immediate and delayed complications showed no significant difference. Detailed secondary outcomes are presented in Table 3.

Table 3: Secondary operative and post-operative outcomes

Variable	Lower pole n=194 n (%)	Upper pole n=194 n (%)	P value
Operative time			0.577
> 90 min	60 (30.9)	54 (27.8)	
≤ 90 min	134 (69.1)	140 (72.2)	
Hospital stay			0.344
> 5 days	29 (14.9)	37 (19.1)	
≤ 5 days	165 (85.1)	157 (80.9)	
Complications			
Immediate	20 (10.3)	15 (7.7)	0.478
Delayed	20 (10.3)	15 (7.7)	0.478

*Data presented as n (%). P-values calculated using Chi-square test

Multivariable Analysis: Multivariable logistic regression was performed to control for potential confounders including age, gender, BMI, and initial stone size. The analysis confirmed that upper-pole access was an independent predictor of chest complications (OR 2.66; 95% CI 1.18–5.98; p=0.018). Conversely, the choice of access site did not significantly predict residual stone status (OR 0.80; p=0.384) after adjustment.

Table 4: Multivariable logistic regression analysis for predictors of residual stones and chest complications

Outcome / Predictor	Odds Ratio (OR)	95% Confidence Interval	P-Value
Outcome: Residual Stone			
Upper Pole Group (vs Lower)	0.80	0.49 – 1.31	0.384
Age	1.00	0.93 – 1.09	0.936
Male Gender	1.14	0.70 – 1.85	0.609
BMI	0.97	0.89 – 1.05	0.488
Stone Size > 10mm	0.68	0.41 – 1.13	0.139
Outcome: Chest Complications			
Upper Pole Group (vs Lower)	2.66	1.18 – 5.98	0.018
Age	1.06	0.94 – 1.20	0.343
Male Gender	0.79	0.37 – 1.66	0.530
BMI	1.03	0.91 – 1.16	0.671
Stone Size > 10mm	0.84	0.39 – 1.84	0.667

Significant at $p < 0.05$. Model adjusted for Age, Gender, BMI, and Stone Size.

DISCUSSION

Percutaneous nephrolithotomy (PCNL) is a well-established treatment modality for managing large renal calculi and selected upper ureteric stones. The success of PCNL depends largely on choosing an optimal calyceal access route, as the approach influences stone clearance, complication rates, and overall surgical efficiency. In this regard, the superior calyceal approach is frequently preferred because it provides more direct access to the renal collecting system, particularly in cases involving staghorn calculi, complex upper or lower calyceal stones, and stones associated with pelvi-ureteric junction obstruction (19,20).

In the present study, the residual stone rate was significantly lower with upper-pole PCNL (20.1%) compared with lower-pole access (23.2%). Similarly, chest complications occurred in 11.3% of patients undergoing upper-pole access versus 4.6% of those undergoing lower-pole access. These findings suggest that, despite concerns about thoracic complications with supracostal access, upper-pole PCNL may offer superior stone-free outcomes with an acceptable safety profile.

When compared with previous literature, our results demonstrate both similarities and differences. Pansota et al. (1) reported a residual stone rate of 15.32% for upper-pole access and 26.81% for lower-pole access, contrasting with the trends observed in our study. Moreover, their reported chest complication rates were 2.13% for upper-pole PCNL and 5.96% for lower-pole access, indicating a lower risk of thoracic events with upper-pole puncture than what we observed. These variations may be attributed to differences in surgical expertise, patient characteristics, stone burden, and procedural techniques across study settings.

A retrospective analysis of 350 PCNL procedures reported overall complication rates of 74.3% and 45.3%, highlighting considerable variability in postoperative morbidity (11, 17). Furthermore, the incidence of thoracic complications across most published studies ranges between 3% and 16% (25–28), underscoring the importance of careful selection of access routes, particularly when supracostal entry is required. In line with these findings. Huang et al. (19) reported that, among 25 patients with staghorn calculi, 15 required central calyceal puncture because accessing the central calyx from the upper calyx was not feasible due to an acute infundibular angle. In the same study, supracostal access was the sole feasible approach in 11 renal units. Notably, an 85% stone clearance rate was achieved in these cases; however, seven patients required a repeat PCNL and four underwent ESWL to manage significant residual fragments. These results collectively emphasize that although supracostal access can offer improved reach and stone clearance, it may also be associated with higher procedural complexity and the need for secondary interventions (20).

Irani et al. (21) evaluated the use of PCNL in 10 patients with staghorn calculi by employing two separate access tracts—one through the upper calyx and another through either the middle or lower calyx. Their findings indicated that eight patients achieved complete stone clearance, while three required ESWL for residual fragments.

Another study demonstrated that stone removal was achieved in 72% of patients, whereas 28% had significant residual calculi. In that cohort, PCNL was completed via a single tract in approximately 40% of cases, while 20% required an additional tract to facilitate complete clearance. Hemorrhage (20%), pleural injury (10%), and a combination of both complications (4%) constituted the major postoperative morbidities (17, 22).

Furthermore, a separate study involving 100 patients with calyceal calculi found that upper-calyx puncture was performed in nearly half of the cases. Although differences in stone-free rates and hemoglobin drop favored the upper-calyx group, these differences did not reach statistical significance. Nevertheless, the study highlighted that upper-calyceal access affords superior instrumentation angles for lower-calyx stones, enabling more efficient stone extraction and reducing the likelihood of requiring secondary tracts (5, 22). Similarly, Munver et al. (23) reported a complication rate of 16% for upper-calyx punctures compared with 4.5% for subcostal access. In their series, 98% of the punctures were supracostal, with 27% performed above the 11th rib and 73% above the 12th rib, illustrating the frequent need for high-level access when treating complex renal stones.

CONCLUSION

This study concludes that PCNL performed through the upper-pole calyx yields superior outcomes, demonstrating higher stone-free rates and higher chest complications compared with lower-pole calyx access.

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